An Examination of LENR Design Imporovements, Based on Recently Gained Undersatnding of the LENR Mechanisms: A Conventional Explanation of LENR Updated 2023

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Outline

1. Review of Previous Presentation
2. Neutron scattering and neutron reactions (no neutrons escape)
3. Gamma radiation (very little gamma)
4. Energy to ^{4}He ratio
5. Electronic Stopping and Lattice Assisted Nuclear Reactions
6. Experimental ways to increase the probability of a chain reaction

Review of Previous Talk—Primary and Secondary Reaction in a LENR

- Consider a LENR in steady state.
  - Two Primary reactions:

    $^2d+^2d \rightarrow {}^3t+p$ and $^2d+^2d \rightarrow {}^3He+n$.
  - Two Secondary reactions:

    $^2d+^3t \rightarrow {}^4He+n$ and $^2d+^3He \rightarrow {}^4He+p$.
  - Normal Physics explains it.
    - Very little gamma. At the experimentally observed energy.
    - No neutrons coming out of the setup.
    - The ^4He/energy ratio is correct.
- No Weirdness required:
  - No unexplained enhancement of $^2d+^2d \rightarrow {}^4He+\gamma$ reaction.
  - No novel ways needed to overcome the Coulomb barrier.
  - No unusual physics is needed at all.
- The Mechanism:
  - Child products collide with cold ^2d
  - Frequently and energetically enough.
  - Sustains the ^2d to ^2d reaction.
  - The conditions in the lattice must be right.

Review of Previous Talk--Calculations for an Example LENR Reactor

Primary 1 reaction: $^{2}d+^{2}d \rightarrow {}^{3}t+p$
Primary 2 reaction: $^{2}d+^{2}d \rightarrow {}^{3}He+n$
Secondary 1 reaction: $^{2}d+^{3}t \rightarrow {}^{4}He+n$
Secondary 2 reaction: $^{2}d+^{3}He \rightarrow {}^{4}He+p$

- The released energies of the primary and secondary reactions are kinetic energies.
- Eight different child products, total.
- Let's examine a numerical example, using a typical electrolytic set-up in steady state.

For the Typical Example Reactor:

- 1 watt from the primary reactions
- Reaction rate is 1.71×10^{12} per sec.
  - This is 8.55×10^{11} reactions/second for *each* primary reaction.
  - The palladium core is 1 cm^3.
  - The NAE has 10X of 100% loading.
  - Typical electrolytic set-up.
- Charged child products (^{1}H, ^{2}d, ^{3}t, ^{3}He, and ^{4}He) are trapped in Pd Core.
- Energetic neutrons escape the Pd core.
  - But not the reactor set-up.
  - To be shown in later slide.

Review of Previous Talk--Calculations for an Example LENR Reactor

- Lengthy and complicated.
  - Conventional physics
- For each child product, calculate:
  - Scattering rate
  - Amount of energized ^{2}d
  - Average energy.
- The final result is in green on right.
  - 7.4425×10^{12} energetic ^{2}d's.
  - Average energy = 0.5976 MeV.

Projectile	Source of projectile	initial energy of projectile, in MeV	number of energized D-2 from this projectile	total average energy in MeV for this energized D-2	number of energized D-2 multiplied by the average energy of the D-2
Proton	Primary1	3.0300	3.7008E+11	0.20895	7.733E+10
T3	Primary1	1.0100	3.1296E+11	0.19762	6.185E+10
neutron	Primary2	2.4525	1.1296E+12	0.27460	3.102E+11
He3	Primary2	0.8175	1.2099E+12	0.81396	9.848E+11
He4	Secondary1	3.5180	2.1892E+12	0.40724	8.915E+11
neutron	Secondary1	14.0720	6.1192E+11	0.29634	1.813E+11
He4	Secondary2	3.6800	1.3611E+12	0.29295	3.987E+11
Proton	Secondary2	14.7200	2.5775E+11	5.98352	1.542E+12
		Sum =	7.4425E+12	Sum =	4.448E+12
	Average energy of all energized D-2 =			0.5976	MeV

Is this Enough for a Chain Reaction?

- NAE has very high loading of ^{2}d.
- The core volume is 1 cm^3.
- Shape is rolled up thin sheet.
- Needed for chain reaction:
  1.71×10^{12} reactions/sec.
- We have 1.979×10^{12}
- Yes! A chain reaction occurs.

(But, I am ignoring electron stopping.)

A	B	C	D	E	F	G	H
Lab energy range of projectile ion, in MeV	Introduction rate of projectile ion in #/cm^3/sec	Average total distance travelled before the energy drops to next level, in cm.	Reaction cross section at this lab energy, in cm^2.	Reaction rate at this energy, in #/cm^3/sec.	The fraction of the lost projectiles due to reaction.	Percentage of the lost projectiles due to escape.	Amount of energetic D-2 remaining in NAE after the energy drops to next level.
0.598 to 0.55	7.4425E+12	0.5263	1.61E-25	4.275E+11	0.05744	1%	6.9449E+12
0.55 to 0.50	6.9449E+12	0.5113	1.540E-25	3.719E+11	0.05354	1%	6.5073E+12
0.50 to 0.45	6.5073E+12	0.4671	1.48E-25	3.059E+11	0.04701	1%	6.1394E+12
0.45 to 0.40	6.1394E+12	0.4230	1.39E-25	2.455E+11	0.03998	1%	5.8350E+12
0.40 to 0.35	5.8350E+12	0.3789	1.3E-25	1.954E+11	0.03349	1%	5.5831E+12
0.35 to 0.30	5.5831E+12	0.3349	1.18E-25	1.500E+11	0.02687	1%	5.3788E+12
0.30 to 0.25	5.3788E+12	0.2910	1.06E-25	1.128E+11	0.02098	1%	5.2133E+12
0.25 to 0.20	5.2133E+12	0.2473	8.9E-26	7.804E+10	0.01497	1%	5.0839E+12
0.20 to 0.15	5.0839E+12	0.2041	7.2E-26	5.080E+10	0.00999	1%	4.9828E+12
0.15 to 0.10	4.9828E+12	0.1618	5.2E-26	2.851E+10	0.00572	1%	4.9047E+12
0.10 to 0.05	4.9047E+12	0.1229	3.2E-26	1.312E+10	0.00267	1%	4.8427E+12
			Sum =	1.979E+12			

Neutron Scattering and Neutron Reactions

- Energetic Neutrons **escape** the Pd core.
- **Scatter** in the set-up.
  - High scattering rate
  - In Electrolyte
  - In Thermal water bath.
- If a neutron scatters once, then
  - Scattering cross section is larger.
  - More likely to re-scatter.
  - Quickly **thermalizes**.

The Question is: Can the typical set-up scatter all the energetic neutrons at least once?

Again, let's do the math, using highest energy neutrons (14 MeV) as a worst case.

- One watt of power from primary reactions.
- 97% of the hot t-3 react with cold d-2 (14 MeV neutrons).
- The electrolyte is in a cylindrical beaker, with an inner radius of 2.5 cm, and 25 cm tall.
- There is 0.1 mole, 0.694 gm, of lithium in the heavy water.
- The two borosilicate glass beakers are 1/2 cm and 1 cm, thick respectively.
- The thermal water bath extends 25 cm (about 10") beyond the first beaker.
- The whole set-up has a radius of 28.5 cm x 30 cm tall.

Neutron Scattering and Neutron Reactions

The scattering rate is calculated for <u>each part</u>, for <u>each element</u> of the set up:

- ^{2}D and Pd in core.
- ^{2}D, ^{16}O, ^{6}Li in electrolyte
- ^{10}B, ^{16}O, ^{28}Si in 1st Pyrex
- ^{1}H, ^{16}O in water bath
- ^{10}B, ^{16}O, ^{28}Si in 2nd Pyrex

The total % probability for one scattering is highlighted in green.

Under these typical conditions, <u>all</u> neutrons are scattered <u>at least once</u> before escaping.

Inside the Core: the Pd and NAE	Scattering Cross section at this energy with D2 in NAE, in barns.	Distance the average neutron travels going through all the NAE's in the core, in cm.	Density of D2 in NAE, in atoms/cm^3	Percentage probability of a neutron scattering with D2 atom at this energy.	Scattering Cross section at this energy with Pd, in barns.	Distance the average neutron travels before leaving the Pd core in cm.	Density of Pd atoms, in atoms/cm^3	Percentage probability of a neutron scattering with Pd atom at this energy.	Total percentage of original amount that escapes the core without scattering.					Total % that: escapes the core=72%
	0.635	0.1	6.800E+23	4.318	2.50	1.3434	6.803E+22	22.849	72.833					
Inside the heavy water electrolyte: the deuterium, oxygen, and lithium	Scattering Cross section at this energy with D2 in heavy water, in barns.	Distance the average neutron travels before leaving the electrolyte, in cm.	Density of D2 atoms in electrolyte, in atoms/cm^3	Percentage Probability of original amount, of a neutron scattering with D2 atom in electrolyte, at this energy.	Scattering Cross section at this energy with O16 in Electrolyte, in barns.	Distance the average neutron travels before leaving the electrolyte in cm.	Density of oxygen atoms in electrolyte, in atoms/cm^3	Percentage Probability of original amount, of a neutron scattering with O16 atom in electrolyte, at this energy.	Scattering Cross section at this energy with Lithium in Electrolyte, in barns.	Distance the average neutron travels before leaving the electrolyte in cm.	Density of all Lithium atoms in electrolyte, in atoms/cm^3	Percentage Probability of original amount, of a neutron scattering with Lithium atom in electrolyte, at this energy.	Total percentage of <u>original</u> amount that escaped both the Pd core and the electrolyte without scattering or reacting.	escapes both core and electrolyte = 63%
	0.635	2.5	6.684E+22	7.729	1.0	2.5	3.342E+22	6.086	0.997	2.5	1.230E+20	0.022	62.5	
Inside the first borosilicate glass beaker	Scattering Cross section at this energy with boron in Pyrex, in barns.	Distance the average neutron travels before leavingthe Pyrex, in cm.	Density of all boron atoms in Pyrex, in atoms/cm^3	Percentage Probability of original amount, of a neutron scattering with Boron atom in Pyrex, at this energy.	Scattering Cross section at this energy with O16 in Pyrex, in barns.	Distance the average neutron travels before leaving the Pyrex in cm.	Density of all oxygen atoms in Pyrex, in molecules/cm^3	Percentage Probability of original amount, of a neutron scattering with O16 atom in electrolyte, at this energy.	Scattering Cross section at this energy with Si28 in Pyrex, in barns.	Distance the average neutron travels before leaving the Pyrex in cm.	Density of all Silicon atoms in Pyrex, in atoms/cm^3	Percent Probability of original amount, of a neutron scattering with Si atom in electrolyte, at this energy.	Total percentage of <u>original</u> amount that escapes the core, electrolyte, and pyrex without scattering or reacting.	escapes core, electrolyte, and 1st pyrex = 62%
	0.815	0.5	5.588E+21	0.143	0.5	1	1.223E+22	0.384	0.720	0.5	8.780E+21	0.198	62.0	
Inside the thermal water bath	Scattering Cross section at this energy with H1 in water bath, in barns.	Distance the average neutron travels before leaving the water bath, in cm.	Density of H1 atoms in water bath, in atoms/cm^3	Percentage Probability of original amount, of a neutron scattering with H1 atom in the water bath, at this energy.	Scattering Cross section at this energy with O16 in water bath, in barns.	Distance the average neutron travels before leaving the water bath, in cm.	Density of O16 atoms in water bath, in atoms/cm^3	Percentage Probability of original amount, of a neutron scattering with O16 atom in the water bath, at this energy.	Total percentage of original amount that escapes the core, electrolyte, pyrex, and waterbath without scattering or reacting.					escapes core, electrolyte, pyrex, and water bath = -11%
	0.688	25	6.691E+22	71.699	1.0	25	2.974E+22	46.317	-11.224					
Inside the second borosilicate glass beaker	Scattering Cross section at this energy with boron in Pyrex, in barns.	Distance the average neutron travels before leavingthe Pyrex, in cm.	Density of all boron atoms in Pyrex, in atoms/cm^3	Percentage Probability of original amount, of a neutron scattering with Boron atom in Pyrex, at this energy.	Scattering Cross section at this energy with O16 in Pyrex, in barns.	Distance the average neutron travels before leaving the Pyrex in cm.	Density of all oxygen atoms in Pyrex, in molecules/cm^3	Percentage Probability of original amount, of a neutron scattering with O16 atom in electrolyte, at this energy.	Scattering Cross section at this energy with Si28 in Pyrex, in barns.	Distance the average neutron travels before leaving the Pyrex in cm.	Density of all Silicon atoms in Pyrex, in atoms/cm^3	Percentage Probability of original amount, of a neutron scattering with Si atom in electrolyte, at this energy.	Total percentage of original amount that escapes the core, electrolyte, and pyrex without scattering or reacting.	escapes core, electrolyte, 1st pyrex, water bath and 2nd pyrex = -11.2%
	0.815	1	5.588E+21	-0.051	1.0	0.5	1.223E+22	-0.069	0.720	1	8.780E+21	-0.0710	-11.2	

Neutron Scattering and Neutron Reactions

❑ For **Thermal Neutrons,** these four nuclear reactions will absorb them. Notice, more ^{4}He and heat are created.

1. $^{105}Pd + n \rightarrow {}^{106}Pd$ + gamma.
   - The reaction rate is not enough to change isotopic ratio.
2. $^{6}Li + n \rightarrow {}^{4}He + {}^{3}t$.
   - Cross section of **941** barns.
   - Used in hot fusion reactors
     - Stop neutrons
     - Generate heat.
3. $^{10}B + n \rightarrow {}^{4}He + {}^{7}Li$.
   Cross section is **3840** barns.
   Used as neutron moderator in fission reactors.
   Contained in any borosilicate glass (Pyrex or Dewars) in the set-up.
4. $^{1}H + n \rightarrow {}^{2}H$ + gamma
   - High density of ^{1}H in water bath.
   - Used to shield neutrons in fission reactors.

❑ In a typical set-up, how many of the thermal neutrons will react, and how many escape?

Neutron Scattering and Neutron Reactions

The thermal neutron reaction rate is calculated for every part, in every element of the set up:

- ^{2}D and Pd in the core.
- ^{2}D, ^{16}O, ^{6}Li in the electrolyte
- ^{10}B, ^{16}O, ^{28}Si in the 1st Pyrex beaker
- ^{1}H, ^{16}O in the water bath
- ^{10}B, ^{16}O, ^{28}Si in the 2nd Pyrex beaker

The total % probability of a thermal neutron reaction is shown in green.

Under these typical conditions, all thermal neutrons react and do not escape.

In Pd core and NAE

Volume of the NAE for the total sample, in cm^3	Distance the average neutron travels before leaving the NAE's, going through the core, in cm.	Density of D2 in NAE, in number per cm^3	Neutron to D2 reaction cross section at this energy, in barns.	Neutron to D2 reaction rate, per second per cm^3.	Fractional probability of a neutron reacting with a D2 at this energy	Volume of the Pd lattice in the core for the total sample, not including the NAE, in cm^3.	Distance the average neutron travels before leaving the Pd core in cm.	Density of Pd-Natural in Core	Neutron to Pd-Natural reaction cross section at this energy, in barns.	Neutron to Pd-Natural reaction rate	Fractional probability of a neutron reacting with a Pd-Natural at this energy			Total % that reacts in the core =
0.60	0.2	6.80E+23	5.00E-04	8.71E+02	5.15E-10	2.00	1.26E+00	6.80E+22	7.17E+00	2.62E+07	1.55E-05			0.00155

In electrolyte

Volume of the electrolyte for the total sample, in cm^3	Distance the average neutron travels before leaving the electrolyte, in cm.	Density of D2 in electrolyte, in number per cm^3	Neutron to D2 reaction cross section at this energy, in barns.	Neutron to D2 reaction rate, per second per cm^3.	Fractional probability of a neutron reacting with a D2 at this energy	Density of O16 in electrolyte, in number per cm^3	Neutron to O16 reaction cross section at this energy, in barns.	Neutron to O16 reaction rate	Fractional probability of a neutron reacting with a O16 at this energy	Density of Li6 in electrolyte, in number per cm^3	Neutron to Li6 reaction cross section at this energy, in barns.	Neutron to Li6 reaction rate	Fractional probability of a neutron reacting with a Li6 at this energy	Total % that reacts in the elec-trolyte =
491	5	6.68E+22	5.00E-04	1.75E+06	1.03453E-06	3.34E+22	2.00E-04	3.50E+05	2.06906E-07	9.57E+18	9.40E+02	4.72E+08	2.79E-0	0.02799

In borosilicate glass surrounding electrolyte

Volume of the borosilicate glass around electrolyte, in cm^3	Distance the average neutron travels before leaving the borosilicate glass, in cm.	Density of B10 in borosilicate glass, in number per cm^3	Neutron to B10 reaction cross section at this energy, in barns.	Neutron to B10 reaction rate, per second per cm^3.	Fractional probability of a neutron reacting with a B10 at this energy	Density of O16 in borosilicate glass, in number per cm^3	Neutron to O16 reaction cross section at this energy, in barns.	Neutron to O16 reaction rate	Fractional probability of a neutron reacting with a O16 at this energy	Density of Si28 in borosilicate glass, in number per cm^3	Neutron to Si28 reaction cross section at this energy, in barns.	Neutron to Si28 reaction rate	Fractional probability of a neutron reacting with a Si28 at this energy	Total % that reacts in the 1st Pyrex =
215.98	1	1.11E+21	3.85E+03	1.98E+10	1.17E-02	1.22E+22	2.00E-04	1.13E+04	6.65E-09	8.78E+21	1.80E-01	7.29E+06	4.31E-0	1.16704

Light water in water bath

Volume of the light water in water bath, in cm^3	Distance the average neutron travels before leaving the borosilicate glass, in cm.	Density of H1 in light water, in number per cm^3	Neutron to H1 reaction cross section at this energy, in barns.	Neutron to H1 reaction rate, per second per cm^3.	Fractional probability of a neutron reacting with a B10 at this energy	Density of O16 in light water in water bath, in number per cm^3	Neutron to O16 reaction cross section at this energy, in barns.	Neutron to O16 reaction rate	Fractional probability of a neutron reacting with a O16 at this energy					Total % that reacts in the water bath =
73183.40	40	6.69E+22	3.35E-01	1.40E+12	8.28E-01	2.97E+22	2.00E-04	3.71E+08	2.19E-04					82.79477

Borosilicate glass around light water

Volume of the borosilicate glass around light water, in cm^3	Distance the average neutron travels before leaving the borosilicate glass, in cm.	Density of B10 in borosilicate glass, in number per cm^3	Neutron to-B10 reaction cross section at this energy, in barns.	Neutron to B10 reaction rate, per second per cm^3.	Fractional probability of a neutron reacting with a B10 at this energy	Density of O16 in borosilicate glass, in number per cm^3	Neutron to O16 reaction cross section at this energy, in barns.	Neutron to O16 reaction rate	Fractional probability of a neutron reacting with a O16 at this energy	Density of Si28 in borosilicate glass, in number per cm^3	Neutron to Si28 reaction cross section at this energy, in barns.	Neutron to Si28 reaction rate	Fractional probability of a neutron reacting with a Si28 at this energy	Total % that reacts in the 2nd Pyrex =
5372.12	2	1.11E+21	3.85E+03	9.83E+11	5.80E-01	1.22E+22	2.00E-04	5.60E+05	3.31E-07	8.78E+21	1.80E-01	3.63E+08	2.14E-0	58.05589

Sum of reaction probabilites, in % = 142.05

Gamma Radiation from the Set-up

Gamma is due to thermal neutron absorption: $^{A}(X) + n \rightarrow {}^{A+1}(X) + \gamma$

To calculate the gamma radiation:

- Determine the number of thermal neutrons. **(Already Done.)**
- Calculate the number of thermal neutron absorption reactions per second. **(Already Done.)**
- Determine energy and intensity of gamma. **(Done below.)**
- And how much gamma is absorbed by the set-up. **(Done below.)**

Reaction	Energy of gamma radiation in MeV	Initial Intensity of the gamma radiation in gamma rays per second	Post intensity of the gamma radiation after penetrating 25 cm of water	Estimated post-intensity of the gamma radiation after penetrating 1 cm of borosilicate glass	Post intensity of this gamma after passing through both water and borosilicate glass.
D2+n	6.26	1.23E+06	1.99E+05	1.13E+06	1.82E+05
Pd105+n	9.56	1.85E+07	2.98E+06	1.69E+07	2.72E+06
O16+n	4.14	2.62E+08	4.23E+07	2.40E+08	3.87E+07
Si28+n	8.473	2.46E+08	3.97E+07	2.25E+08	3.63E+07
H1+n	2.22	9.87E+11	2.46E+11	9.02E+11	2.25E+11
				Sum=	2.25E+11

- Note the numbers in green. These dominate.
- This model predicts a small amount of gamma at 2.22 MeV.
- This is seen experimentally.

Excess Heat Compared to ^{4}He

	Heat Energy Released	Amount of ^{4}He Produced
Primary reactions:	1 watt.	No ^{4}He is produced.
Secondary reactions:	3.39 watts	$8.421 \times 10^{11} + 3.480 \times 10^{11} = 11.901 \times 10^{11}$
Totals:	4.39 watts	1.1901×10^{12}

Ratio: (4.39 joules/sec) / (1.1901×10^{12} ^{4}He/sec) = 3.7×10^{-12} joules per ^{4}He

= 23.05 MeV per ^{4}He.

- This energy is right on target.
  - Not coincidence.
  - Going from two ^{2}D to ^{4}He, a NET release of energy, no matter what path is taken.
  - Simple conservation of energy.
- There is **more ^{4}He** and **more energy** created in the lithium and boron.
  - Experimentally, the exact ratio has slight **variations**—it **depends on the set-up**.

Electron Stopping Power

Thus, this model answers the questions, explains the experimental data, gives the right values. No miracles. No unexplainable behaviors. No violations of thermodynamics.

😖 Except for one thing… Electron Stopping Power.

- 🙂 This came to my attention last year.
- 🙂 I thought this would reduce the reaction by a factor of 8 or so.
- 🙂 I thought changing the shape of the core could accommodate this.
  - Changing the shape works, but not enough.
- 🙂 I thought I could reduce the excess heat output.
  - Excess heat is <u>not</u> a factor for the chain reaction.
- ☠️ <u>Bottom Line</u>: Electron Stopping power <u>kills</u> the reaction.

The formula for electron stopping S as a function of velocity v is:

$$S(v) = \frac{4\pi n}{m_e v^2} Z^2 k_e^2 e^4 log\left(\frac{2m_e v^2}{I}\right)$$

where I is the average excitation energy--experimentally determined for each material.

Electron Stopping Power and LANR

What are some *possible* ways to reduce or mitigate Electron Stopping Power?

- Apply a counter electric field to motivate the ions forward.
- Use a superconducting material as the core.
- Reduce the electron coefficient of heat.
- Apply a strong magnetic field.
- Increase the temperature.
- Increase the current.
- Ionization.

Is there something is occurring **in the lattice**, maybe more than one thing, that allows the subsequent ^{2}d-to-^{2}d reactions to occur?

After all, we DO call the phenomenon:

Lattice Assisted Nuclear Reactions.

Electron Stopping and LANR
Interesting facts about the PdD_x lattice:

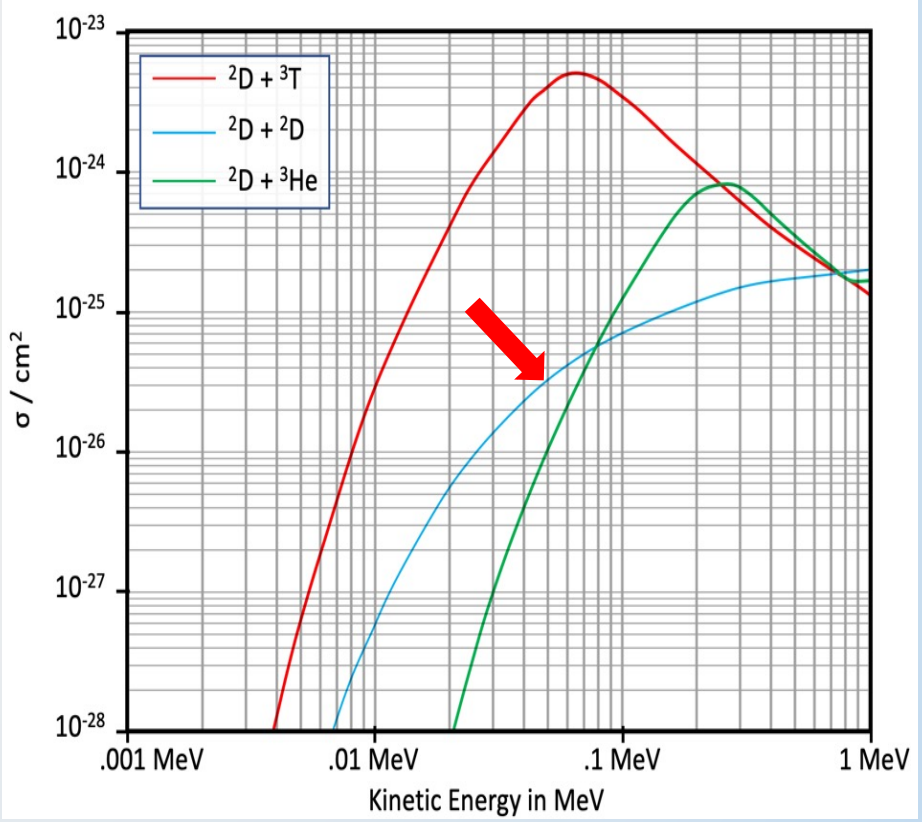
- **Superconductivity**
  - PdD_x is a superconductor.
    - An unconventional high-temperature superconductor.
    - It's behavior can't be explained by any theory. (Sound familiar?)
    - The experimental data for its superconducting behavior is not always reproducible. (Sound familiar?)
  - Theory for conventional superconductors tells us that electrons pair up
    - To form "Cooper pairs"
    - Due to an unknown undefined unexplained attractive force. (Seriously.)
  - Superconductivity is strongly related to current density and magnetism.
    - Superconductivity must have a critical current density, J_c.
    - When superconducting, the normal magnetic field caused by a current flowing in a wire, goes away.

Electron Stopping and LANR
Interesting facts about the PdD_x lattice:

- **PdD_x has *ionized* ^{2}d in it.**
  - The ^{2}d is <u>metallic</u> hydrogen.
  - This accounts for the high absorption of ^{2}d in Pd.
- **The electrons in PdD_x do not follow rules for filling electron shells.**
  - The electrons in Pd fill a higher level d-shell before filling the lower s-shell.
  - The β-phase of PdD_x is characterized by s-electrons filling the d-band.
  - Complexities of the electron quantum mechanics.
- **Magnetic Susceptibility**
  - The magnetic susceptibility of PdD_x varies significantly with x.
  - PdD_x changes from being paramagnetic to diamagnetic as x increases
  - Going from alpha to beta phase.

Electron Stopping and LANR
More Interesting Facts about the PdD_x lattice:

- **There are 2 Heat Coefficients: Atomic and Electronic.**
- **The Electronic Heat Coefficient is γ , gamma.**
  - γ is dependent on the electron density of states.
  - For pure Pd, γ = 9.5 mJ/(mol·K^2).
  - For PdD_x, γ is 6x smaller than for pure Pd.
  - The electrons vibrate more.
  - This is the superconducting region for PdD_x.
- **The ^2D to ^2D reaction curve.**
  - It is not a cliff-like drop-off at low energies.
  - Rather, a gradual sloped drop-off.
  - Due to tunneling (or other effect) overcoming
  - the Coulomb barrier.
  - (The Electromagnetic Model explains this. See my poster.)



Electron Stopping and LANR
Interesting facts about Superconductors

When excited ions are traveling inside a lattice, there are two ways that defects are created:

- Elastic displacement.
  - Collision by charged ionic particles with other nuclei.
  - Related to nuclear stopping, S_n.
- Electron excitation.
  - Collision by charged ionic particles with the electrons.
  - Related to electron stopping, S_e.
- For ion projectiles with an energy below 2 MeV
  - Experimental evidence implies
  - Superconductors are dominated by nuclear stopping
  - Not electron stopping.

Quoting from the literature…

Electron Stopping and LANR
Interesting facts about Superconductors

Ishikawa et al. found that for low energy projectiles (≤2MeV), the defect production rate in a superconductor is proportional to the nuclear stopping power, rather than electron stopping.

of the *c*-axis lattice parameter with increasing fluence for all irradiations. The slope of *c*-axis lattice parameter against fluence, which corresponds to the defect production rate, is separated into two contributions; the effect via elastic displacement and the effect via electronic excitation. The former contribution exhibits a linear increase against the nuclear stopping power, S_n. The latter contribution is scaled by the primary ionization rate, dJ/dx, rather than by the electronic stopping power, S_e, and is nearly proportional to $(dJ/dx)^4$.

the value of $(\Delta c/c_0)/\Phi$. For low energy ($\leqslant 2$ MeV) ion irradiation, $(\Delta c/c_0)/\Phi$, which corresponds to the defect production rate, is proportional to the nuclear stopping power, S_n. On the other hand, for high energy (80 MeV–3.80 GeV) ion irradiation, the contribution of electronic excitation to

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From Barbour et al.:

> "For ions with energies less than several MeV, the dominant mechanism causing irradiation-induced degradation of T_c is collisional damage."

In other words, the damage in the lattice is created by collisions, which implies S_n is the dominant stopping power.

This is in agreement with previous experiments:

> "The defect production rate, which is obtained from the initial slope of the resistance–fluence curve, is almost proportional to the nuclear stopping power, S_n. The T_c depression due to irradiation is also nearly proportional to S_n. These results indicate that the defect production process is dominated by elastic displacement. ……. In high-T_c superconductor $EuBa_2Cu_3O_y$ irradiated with 2 MeV electrons and 0.5–2.0 MeV ions, the normal-state resistance change and T_c depression due to irradiation are nearly proportional to S_n, indicating that the elastic displacement is a dominant damage production process."

In other words, these other behaviors of the lattice that follow this same trend, S_n dominates.

There is <u>something</u> going on in the lattice that mitigates the electron stopping power.

Experimental ways to Increase the Probability of a Chain Reaction:

- **What can we change experimentally to build a better reactor?**
  - The ^{2}d density doesn't actually play a strong role for the chain reaction.
    - Has to be high enough for the NAE to be formed.
    - Has to be high enough to put the PdD_x lattice is in the super conduction region.
  - Size and shape of the Pd core matter--but to a limited extent.
- **Other things may not directly affect the reaction rate, but they may affect the lattice, the superconductivity, and the electron stopping. CANR.**
  - Current density. Applied voltages. Oscillations of these.
  - Temperature.
  - Magnetism.
  - Homogeneity of the loading.
  - Pressure.

Experimental ways to Increase the Probability of a Chain Reaction:

Use a starter

- Especially for well-shielded set-up
- Could cause intermittency and inconsistency
- Alpha emitter, abutting the core.

Lithium Li-6 and Boron B-10 are good.

- Reduce emission of stray neutrons.
- Pyrex. Dewar. Electrolyte.
- ^{4}He particles come out of electrolyte
- Neutrons were formed and reacted, to create the ^{4}He.

The shape needs to be right.

- One that:
  - Moderates
  - Utilizes
  - Contains the neutrons.
- Excellent shapes, with large surface area.
  - Bundle of thin wires
  - Rolled-up thin foil
  - Porous collection of small Pd grains.

If a neutron escapes the Pd core, it is moderated, scattered, and re-enters another part of the Pd core.

The more we contain the neutrons inside the core and use their energy, the better.

Summary and Conclusions

All the so-called "miracles" of LENR are explained.

- ✓ The Coulomb barrier is overcome by the transference of kinetic energy to the cold ^{2}d.
- ✓ Neutrons are emitted from the reactions, but they do not escape the set-up.
- ✓ Very little gamma radiation occurs, because only the tertiary reactions create them.
- ✓ Gamma occurs at 2.22 MeV, as is verified experimentally.
- ✓ The predicted energy per ^{4}He ratio is on target. Not coincidental.

No unusual or novel physics is needed. Simply apply conventional nuclear physics to the LENR.

EXCEPT…

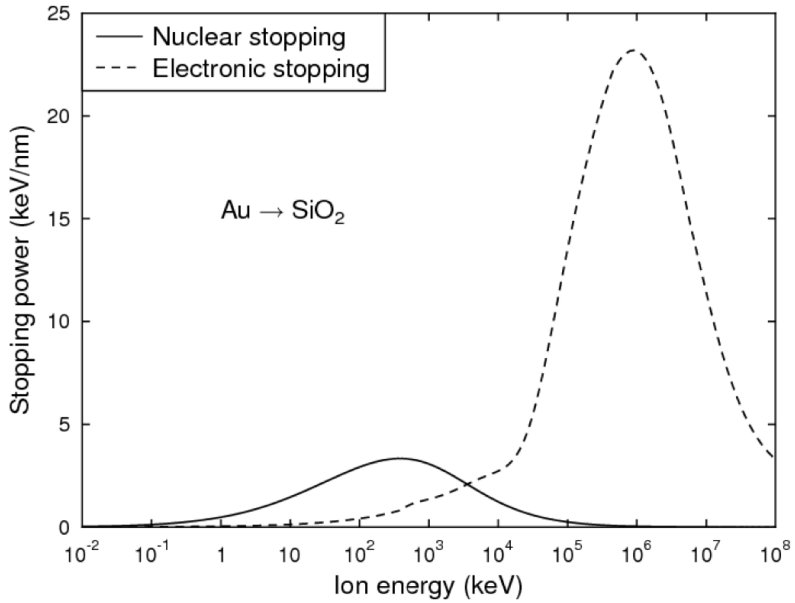
- **…Except** for electron stopping.
- We already know there are unexplained behaviors of superconductivity and the electrons.
- We already know there is something unusual with the electrons occurring in the lattice.
- We don't know exactly WHAT it is.

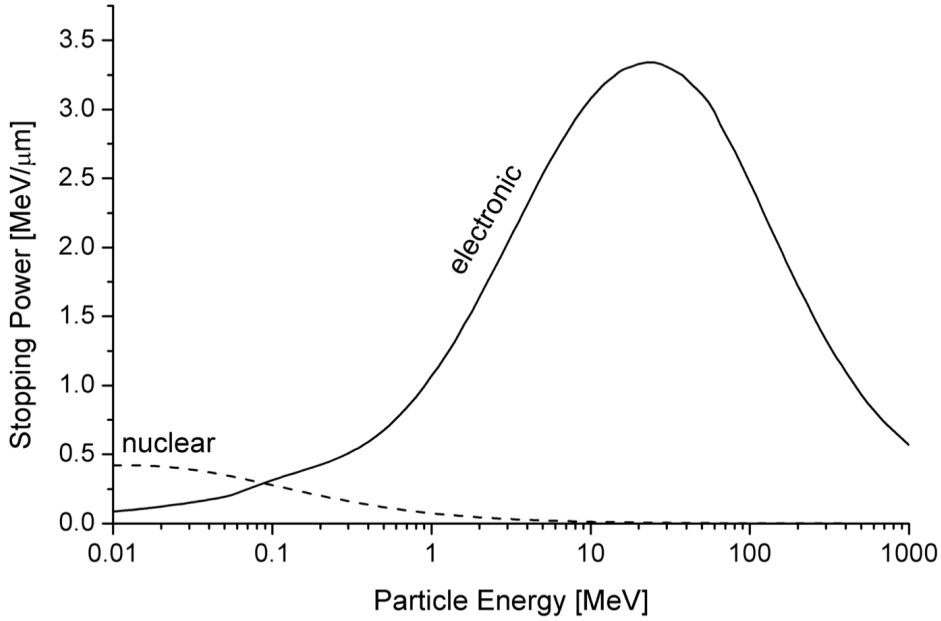
Further research is needed, both theoretically and experimentally, to clarify exactly what is happening.

Conclusions

- A conventional explanation of LENR should not be casually rejected.
- That is an unfortunate assumption, made before actually studying the facts.
- The conventional explanation can explain more experimental behavior than other models.
- These concepts need to be more thoroughly investigated.

Thank you for your attention.


Nuclear stopping
Electronic stopping
Au → SiO2
Stopping power (keV/nm)
Ion energy (keV)
0
5
10
15
20
25
10-2
10-1
1
10
102
103
104
105
106
107
108


electronic
nuclear
Stopping Power [MeV/μm]
Particle Energy [MeV]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0.01
0.1
1
10
100
1000